Kentucky Method 64-501-02
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METHOD OF TEST FOR DETERMINING THE CALIFORNIA BEARING RATIO OF LABORATORY COMPACTED SOILS AND SOIL - AGGREGATE MIXTURES

1. SCOPE: This method describes the procedures employed in determining the California Bearing Ratio (CBR) for Soils or Soil-Aggregate samples when compacted and tested in the laboratory, by comparing the penetration load of the material to that of a standard material.

2. APPARATUS:

    2.1. Loading Device: A compression-type apparatus with a movable head or base such that it is capable of applying a uniformly increasing load up to 60,000 lb at a rate of 0.05 in. per min. The device shall be equipped with a load indicating device that can be read to 10 lb or less.

    2.2. Molds: The molds shall be cylindrical in shape, made of metal, with an internal diameter of 6.0 ± 0.026 in. and a height of 7.0 ± 0.018 in. Each mold shall be machined to fit a removable perforated base and two slotted flanges by means of which it is bolted to its base.

    2.3. Compacting Plunger: A metal unit approximately 5 in. in height with a diameter that allows approximately 0.002 in. clearance with the mold walls. The plunger shall have flat, smooth end surfaces.

    2.4. Surcharge Plates and Weights: A perforated metal disc approximately 5.875 in. in diameter 0.25 in. thick, having in its center a threaded metal stud bolt. This stud is fitted with a threaded lock washer and a threaded sleeve nut. Each surcharge plate shall weigh 2.5 ±0.10 lb and is weighted by removable metal weights, each weighing 5 ± 0.10 lb.

    2.5. Apparatus for Measuring Expansion: A dial indicator is mounted stem downward on a tripod. The unit is designed to be placed on the rim of the mold and permit the stem to make contact with the top of the sleeve nut of the surcharge plate with respect to a datum. The dial indicator shall have a 1 in. throw and read to 0.001 in.

    2.6. Penetration Pin or Piston: A metal pin or piston of circular cross-section having a diameter of 1.954 ± 0.005 in. (area = 3.0 in^2) and approximately 7.5 in. in length.

    2.7. Dial Indicator for Measuring Deformation: The indicator is mounted such that the stem of the indicator is in contact the testing machine head in order to measure the penetration of the specimen. The dial indicator shall have a 1 in. throw and read to 0.001 in.

    2.8. Soaking Tank: A soaking tank suitable for maintaining the water level 1 in. above the top of the molds.

2.9. Miscellaneous: Miscellaneous tools such as mixing pans, spoons, straightedge, filter paper, balances, sieves. moisture content containers, drying oven for determining moisture contents, etc.

3. PROCEDURE:

3.1. Preparation and Design of the CBR Test Specimens:

3.1.1. The material to be used in the CBR test shall have been initially prepared in the manner described by AASHTO T 87. According to AASHTO T 87, samples shall not be subjected to drying temperatures above 140^{o} F; all samples prepared by AASHTO T 87 are considered to be air dried regardless of whether an oven or other drying apparatus is used.

3.1.2. The quantities of material required for a CBR test specimen are computed from the maximum dry density obtained from the KM 64-511 (Moisture-Density Relations) test. It is an amount sufficient to yield a volume of 0.0818 ft^3 in the CBR mold, 5.0 in. in depth and 6.0 in. in diameter, when the material is at optimum moisture condition.

3.1.3. When CBR test specimens are prepared, the hygroscopic moisture content should be determined on the material finer than the No. 4 sieve to properly compensate for the hygroscopic moisture in the specimen design computations. The preferred method of determining the hygroscopic moisture content is by AASHTO T 265 using a minimum sample size of 100 g. If the hygroscopic moisture cannot be determined by AASHTO T 265 due to time or other constraints, AASHTO T 217 may be used.

3.1.4. When material coarser than the No. 4 sieve is to be incorporated into the CBR specimen all such particles shall pass the 3/4 in. sieve.

3.1.5. Masses for the CBR Test Specimen Designs shall be calculated to the nearest gram. Examples of Proper CBR Test Specimen Design Computations are presented in Appendix A.

3.1.6. All materials for the test specimen shall be thoroughly mixed by hand until the mix appears to be approximately uniform.

3.2. Compacting and Soaking Specimen:

3.2.1. After the material has been mixed, it is placed in the mold; it may be necessary to lightly compact the material, by hand, using a mallet, or by another comparable method, to get all the material in the mold. A filter pad with a diameter of approximately 5 in. is visually centered in the mold and placed on top of the specimen. The compaction plunger is inserted into the mold on the specimen and a pressure of 2000 psi, or a load of 56,550 lb is applied gradually over a 2 minute interval.

3.2.2. After removal of the compaction plunger, three surcharge weights and the surcharge plate, totaling 17.5 ± 0.5 lb are inserted into the mold to rest on the compacted specimen.

3.2.3. The specimen is placed in the soaking tank and a height measurement is taken using the indicator mounted on the tripod. The water shall be maintained a minimum of 1 in. above the top of the mold.

3.2.4. The length of time the sample is allowed to remain submerged in the tank is dependent upon the amount of swell indicated by height readings taken daily. Measurements are taken until successive readings (taken 24 hours apart) differ by not more than 0.003 in. The minimum soaking period, regardless of swell, is 3 days and the maximum is 15 days.

3.3. Load Bearing Test:

3.3.1. Following the soaking period the mold is thoroughly drained of free water, the surcharge weights and plate are removed and the mold assembly placed in the loading device. A 5 lb weight is placed on the surface of the specimen, and the loading penetration piston is placed uprightly and centered on the surface of the specimen exposed through the hole in the weight. A seating load of 10 ± 0.2 lb is applied to the piston.

3.3.2. The dial indicator for the penetration reading and the load indicator are zeroed.

3.3.3. The load is applied so that the rate of penetration of the piston into the specimen is 0.05 in. per minute. Load readings are obtained when the depth of penetration has reached 0.010, 0.025, 0.050, 0.075, 0.10, 0.20, 0.30, 0.40, and 0.50 in.

3.4. Calculation of Bearing Ratio:

3.4.1. The penetration stresses (psi) are calculated for all penetration readings and a Stress vs. Penetration curve is plotted. The curve may be concave upward initially because of surface irregularities, or other causes. To obtain the true Stress vs. Penetration relationships, correct the curve having concave upward shape near the origin by adjusting the location of the origin by extending the straight-line portion of the curve downward until it intersects the abscissa. A Typical Stress vs. Penetration plot is shown in Figure 1.

3.4.2. The bearing ratio is calculated by expressing the stress (load per unit area of the penetration pin or piston) at the 0.1, 0.2, 0.3, 0.4, and 0.5 in. penetration depths as a percentage of the following respective standard reference stress values. In all cases, the CBR value assigned to a material is the lowest of the five penetration calculations.

Penetration (in.)	**Standard Reference Stress (psi)**
0.1	1000
0.2	1500
0.3	1900
0.4	2300
0.5	2600

3.4.3. Table 1 illustrates the calculations involved in determining a CBR value. These calculations are applicable to the curve plotted in Figure 1.

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Division of Materials

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APPENDIX A: EXAMPLES OF PROPER CBR TEST SPECIMEN DESIGN COMPUTATIONS

EXAMPLE # 1 - Sample of Soil Only (All Material Finer than the No. 4 Sieve) -

Given Conditions:

(1) KM 64-511 Test Results:

	$\gamma_{d\ max}$	=	110 lb/ft^3	maximum dry density
	w_{opt}	=	14 %	optimum moisture content
(2)	w_{hyg}	=	2.0%	hygroscopic moisture content of the air-dry soil to be used
(3)	V_{mo}	=	0.0818 ft^3	volume of the mold occupied

Calculate the masses of material required for CBR test specimen as follows:

(1) Calculate the theoretical mass of dry soil, M_{ds}.

$$M_{ds} = \gamma_{d\ \max} V_{mo} = \left(110 \ \frac{lb}{ft^3}\right)(0.0818 \ \ ft^3)\left(453.6 \ \frac{g}{lb}\right) = 4081 \ g$$

(2) Calculate the mass of air-dry soil, M_{ads}.

$$M_{ads} = M_{ds}\left(1 + \frac{w_{hyg}}{100}\right) = 4081 \ g \left(1 + \frac{2.0}{100}\right) = 4163 \ g$$

(3) Calculate the mass of water to be added to the air-dry soil, M_{wa}, to bring it to the optimum moisture content.

$$M_{wa} = M_{ds}\left(\frac{w_{opt} - w_{hyg}}{100}\right) = 4081 \ \ g \left(\frac{14 - 2.0}{100}\right) = 490 \ \ g$$

(4) The CBR test specimen design is as follows:

4163 g air-dried soil
490 g water added to soil

EXAMPLE # 2 - Soil-Aggregate Mixture Sample

Given Conditions:

(1) KM 64-511 Test Results:

$\gamma_{d\ max}$	=	125 lb/ft^3	maximum dry density of composite materials
w_{opt}	=	10%	optimum moisture content

(2) F_4 = 60.0% percent finer than the no. 4 sieve

(3) w_{hyg} = 2.0% hygroscopic moisture content of the air-dry soil finer than the no. 4 sieve

(4) V_{mo} = 0.0818 ft^3 volume of the mold occupied

Note: In preparation, or design, of a soil-aggregate sample for the CBR test, it is deemed impractical to make all adjustments and compensations for moisture present in the coarse fraction which would provide for absolute theoretically correct design masses. The procedures and computations illustrated hereinafter are those employed by the Division of Materials, Geotechnical Branch, in the design of a CBR test specimen for a soil-aggregate sample.

Calculate the masses of material required for CBR test specimen as follows:

(1) Calculate the theoretical mass of dry soil finer than the No. 4 sieve, M_{df4}.

$$M_{df}4 = \gamma_{d\ max}\ V_{mo}\left(\frac{F_4}{100}\right) = \left(125\ \frac{lb}{ft^3}\right)(0.0818\ ft^3)\left(\frac{60.0}{100}\right)\left(453.6\ \frac{g}{lb}\right) = 2783\ g$$

(2) Calculate the mass of air-dry soil finer than the No. 4 sieve, M_{adf4}.

$$M_{adf4} = M_{df}4\left(1 + \frac{w_{hyg}}{100}\right) = 2783\ g\left(1 + \frac{2.0}{100}\right) = 2839\ g$$

(3) Calculate the mass of soil coarser than the No. 4 sieve, M_{c4}.

$$M_c4 = \gamma_{d\,\max} V_{mo} \left(1 - \frac{F_4}{100}\right) = \left(125 \frac{lb}{ft^3}\right)(0.0818 \ ft^3)\left(1 - \frac{60.0}{100}\right)\left(453.6 \frac{g}{lb}\right) = 1855\,g$$

Note: In the calculation above it is assumed that the material coarser the No. 4 sieve contains no hygroscopic moisture or the air-dry and dry masses are identical.

(4) Calculate the mass of water to be added to the sample, M_{wa}, to bring it to the optimum moisture content.

$$M_{wa} = (M_{df}4 + M_c4)\left(\frac{w_{opt} - w_{hyg}\left(\frac{F_4}{100}\right)}{100}\right)$$

$$= (2783\,g + 1855\,g)\left(\frac{10 - 2.0\left(\frac{60.0}{100}\right)}{100}\right) = 408\,g$$

(5) The CBR test specimen design is as follows:

2839 g	air-dry soil finer than the no. 4 sieve
1855 g	soil coarser than the no. 4 sieve
408 g	water added to sample

TABLE 1 - CBR CALCULATIONS FROM FIGURE 1 CURVES						
Curve A (No Correction Required)						
Penetration	**Load**	**Stress**	**Corrected Stress**	**Standard**	**CBR**	**Assigned**
0.010	60	20				
0.025	155	52				
0.050	305	102				
0.075	465	155				
0.1	615	205	205	1000	20.5	14.0
0.2	950	317	317	1500	21.1	
0.3	1020	340	340	1900	17.9	
0.4	1068	356	356	2300	15.5	
0.5	1095	365	365	2600	14.0	
Curve B (Corrected for Surface Irregularities)						
0.010	10	3				
0.025	45	15				
0.050	130	43				
0.075	215	72				
0.1	300	100	117	1000	11.7	11.7
0.2	655	218	232	1500	15.5	
0.3	875	292	297	1900	15.6	
0.4	945	315	317	2300	13.8	
0.5	975	325	325	2600	12.5	
Curve C (Corrected for Concave Upward Shape)						
0.010	5	2				
0.025	20	7				
0.050	40	13				
0.075	80	27				
0.1	140	47	92	1000	9.2	
0.2	410	137	182	1500	12.1	9.2
0.3	680	227	260	1900	13.7	
0.4	850	283	295	2300	12.8	
0.5	900	300	302	2600	11.6	

$$Stress\ (psi) = \frac{Load\ (lb.)}{3.0\ in.^2} \qquad CBR = \left(\frac{Corrected\ Stress}{Standard\ Reference\ Stress}\right) x\ 100$$